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RESEARCH AND EDUCATION

Three-dimensional comparative study on the accuracy and reproducibility of dental casts fabricated by 3D printers

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ABSTRACT

Statement of problem. Studies investigating the precision of 3-dimensional (3D) printed casts for fixed prosthodontics are scarce.

Purpose. The purpose of this in vitro study was to compare the accuracy and reproducibility of dental casts made by the conventional method and by 3D printing.

Material and methods. A master model was designed and fabricated with polyetherketoneketone. Ten specimens were fabricated with Type IV dental stone with polyvinyl siloxane. A light scanner was used to scan the master model, and the data were converted to standard tessellation language (STL) files. Three different types of 3D printers (Objet EDEN260V, ProMaker D35, and LC-3Dprint) were used to make 10 specimens each. All specimens were scanned by the light scanner, and the scanned files were superimposed on the files of the master model with specialized software to analyze the volumetric changes. The Kruskal-Wallis test, Mann-Whitney U tests, and Bonferroni method were performed with statistical analysis software (α=.05).

Results. The volumetric changes in casts made by the conventional method and by the 3D printers were significantly different. The conventional casts showed smaller volumetric change than the 3D-printed casts. Significant differences ($P<.05$) were found among the different types of 3D printers. The ultraviolet-polymerizing polymer with digital light processing exhibited the smallest volumetric change. In 3D color maps, the deformations were in similar patterns with all the 3D printers.

Conclusions. The conventional method of die fabrication was more reliable than that of 3D printers. (J Prosthet Dent 2018;■:■-■)

The 3-dimensional (3D) manufacturing industry has grown dramatically in recent years. From industrial facilities to personal devices, the worldwide sale of products related to 3D manufacturing has expanded more than 33% every year,[1] with the medical and dental fields among the fastest-growing markets.[2] To manufacture a product, a selected cast has to be digitized, either by designing in computer software or scanning an actual patient. The direct method is scanning the oral cavity, whereas the indirect method is scanning an impression or cast. The digital data obtained from the scans are converted into standard tessellation language (STL) files, a format compatible with computer software.

Virtual dental casts have contributed to the efficiency of the dental laboratory process. Digitalized casts have the following significant advantages: efficiency, convenience, durability, and space efficiency.[3] However, digitalized casts need to be converted into actual casts for diagnosis or to fabricate appliances. Three-dimensional manufacturing is a method of producing actual casts from the digital data.

The 3D manufacturing process can be categorized into 2 types: subtractive manufacturing (SM) and additive manufacturing (AM). SM, such as computer-aided design and computer-aided manufacturing (CAD-CAM), is based on milling the material. AM, such as 3D printing, is based on adding the material. AM enables the fabrication of complex structures that are difficult to mill. Three-dimensional printing devices are generally based on material jetting and photopolymerization techniques and are used to produce surgical guides and diagnostic casts.[4,5]

Photopolymerization was first introduced commercially in 1983,[6] and its ability to rapidly construct products with smooth surfaces and excellent hardness eventually led to its application in dentistry. Photopolymerization

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Clinical Implications

Three-dimensional printers can be used clinically to diagnosis or duplicate dental casts, but further studies are essential before 3D printers can be used to fabricate dies.

3D printers include PolyJet and digital light processing (DLP) and are considered more sophisticated than other types.[7,8] The ink-jet print heads of the PolyJet deposit tiny drops of building and supporting materials to produce smooth surfaces and high accuracy but lack the ability to reproduce detail and mechanical properties. The mechanism of DLP is like that of stereolithography, polymerizing each layer of light-sensitive resins. This is a fast and highly accurate printing system but is limited in the choice of materials.[4-6] DLPs using ultraviolet (UV) light-emitting diodes (LEDs) are considered better than DLPs using UV.[9]

Accurate impressions and casts are essential for precise fixed prostheses.[10] In the conventional process, polyvinyl siloxane (PVS) has been used as an impression material because of its excellent accuracy and stability.[11] Type IV dental stone has been used as the die material and is more popular than epoxy or polyurethane resin.[12,13] However, the setting expansion and poor wear resistance of dental stones make the fabrication of prostheses difficult.[14-16] Recent studies have reported similar accuracy between conventional and digital impressions.[17]

Digital impressions can be made directly or indirectly. Some studies show that direct impressions are more precise,[18] whereas others do not.[19] Studies of orthodontic diagnostic casts have examined the accuracy of 3D printers[4,5,7,20,21] and found that the casts fabricated by 3D printers meet the acceptable range of discrepancy.[8,22] Previous studies have analyzed the casts by gauging length reproduction,[12,15,23-25] and a recent study has analyzed casts by 3D scanning.[26] This provides a convenient analysis method,[27] but few studies have addressed dental casts fabricated by 3D printers with digital scanning, especially in prosthodontics, where detail reproducibility is key.[28,29]

The purpose of this in vitro study was to compare and analyze the overall volumetric changes of different 3D printing systems by arranging the superimposed surfaces of 4 differently fabricated casts. This study was designed to evaluate the accuracy and reproducibility of the 3D printers for dental cast fabrication. The null hypothesis was that the accuracy of the casts evaluated would be similar.

MATERIAL AND METHODS

A master model was designed with a height of 12 mm, shoulder width of 1.5 mm, and diameter of 13 mm at the cavosurface line angle with a convergence angle of 5 degrees, leading to a diameter of 9 mm at the occlusal surface of the die (Fig. 1).[25] The model was then milled (VHF; Cendres+Métaux SA) from a polyetherketoneketone resin (Pekkton; Cendres+Métaux SA) block.

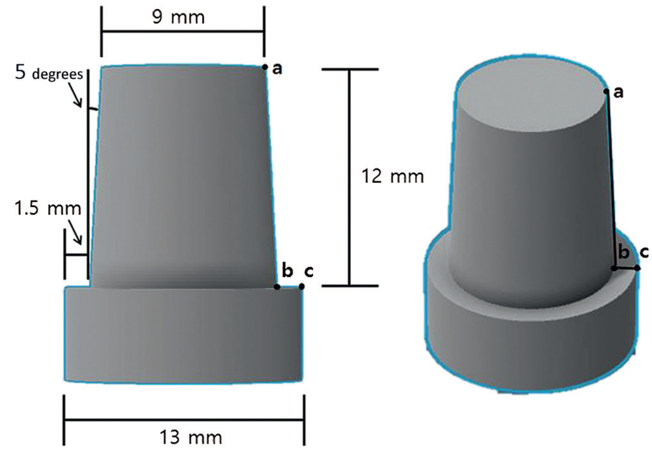

Figure 1. Design of master model (a-b: vertical slope area, b-c: shoulder area).

A stone cast was poured for the fabrication of a custom tray from an irreversible hydrocolloid impression (Alginoplast; Heraeus) of the master model. The tray was fabricated with autopolymerizing tray resin (Quicky; Nissin Dental), and adhesive (Exaflex Adhesive; GC) was applied after removing the baseplate wax spacer. With the custom tray, an impression of the master model was made with polyvinyl siloxane impression materials (Honigum; DMG) by using a 1-step double-mix technique. After removing the impression from the master model, the impression was rinsed under running water before and after disinfection, dried, and stored at 25°C for 30 minutes. A surfactant (Debubblizer Surfactant; Almore Intl, Inc) was sprayed on the impression.[30] Type IV dental stone (GC FujiRock EP; GC) was prepared by vacuum-mixing (Twister Evolution; Renfert) according to the manufacturer's instruction and then poured into the impression. The cast was allowed to set for 40 minutes and was removed from the impression. The above procedures were repeated 10 times to prepare 10 specimens. Also, the master model was scanned with the light scanner (5 Series; Dental Wings) to produce a file for obtaining a dental cast with 3D printers. Scanned data were saved as STL files and with the following 3D printers: PolyJet (Objet EDEN260V; Stratasys Ltd); DLP-UV LED (ProMaker D35; Prodways); and DLP-UV (LC-3Dprint; NextDent). Ten specimens were fabricated from each of the methods (Fig. 2), and 4 groups with 10 specimens were prepared (Table 1).

The fabricated casts were scanned with the light scanner by group after spraying scan powder on the